

Lesson 1

Engage/ Explore

The Brain: What's Going On in There?



Source: National Institute on Drug Abuse (1996) The Brain & the Actions of Cocaine, Opiates, and Marijuana. Slide Teaching Packet for Scientists.

Overview

Students examine images of human brains that illustrate that specific regions of the brain regulate specific functions. They extend that knowledge to learn that drugs of abuse activate an area of the brain called the reward system. The same brain region is stimulated in response to basic survival needs to produce feelings of pleasure.

Major Concept

Specific brain regions control specific brain functions.

Objectives

By the end of these activities, students will

- understand that particular functions are localized to specific areas of the brain,
- appreciate that imaging techniques allow scientists to study activity in the brain, and
- recognize that normal behaviors can activate the reward system in the brain and that drugs of abuse affect those same reward circuits.

Basic Science–Health Connection

The brain controls virtually everything humans experience, including movement, sensing our environment, regulating our involuntary body processes such as breathing, as well as controlling our emotions. Ongoing scientific research into the organization and function of the brain has led, and will continue to lead, to new treatments of diseases such as Parkinson's disease, epilepsy, stroke, and mental illnesses (including depression and schizophrenia).

At a Glance

Background Information

The brain is the organ of behavior. It is also the organ of our mind. Both overt behavior and consciousness are manifestations of the work of our brains. Other people can see an individual's overt behaviors, whereas consciousness is apparent only in our individual minds. The field of neuroscience studies how people control their behaviors, thoughts, and feelings, and how these actions sometimes get out of control.

The brain processes a huge amount of information in a remarkably efficient manner. Think about driving a car. It is something most of us do without much difficulty. But to do it properly, we must perform a remarkable number of tasks. First we have to make sure that our body is in working order. Heart rate and breathing have to be properly regulated, body temperature held steady, and we certainly have to be sure we don't fall asleep. Despite the complexity of these tasks, we carry them out with no conscious involvement on our part. Then, there are the things we are aware of. We have to see the road and hear the traffic (or the radio), use information from our feet, legs, hands, and arms to know where the gas pedal and steering wheel are, and then generate the body movements to control the direction and speed of the car. All of this often takes place while we are talking to someone else in the car, or even while talking on the phone (although this may not be the best idea). The magnitude and speed of data processing needed to do this are stunning, but most of us consider driving to be an easy task.

Different Regions of the Brain Regulate Different Functions

How does the brain carry out multiple tasks at one time? The answer is that the brain splits the larger task—driving, in our example—into smaller ones: seeing, hearing, moving, and so forth. Even those tasks are split into their component parts. One part of the human brain analyzes the movement of objects that we

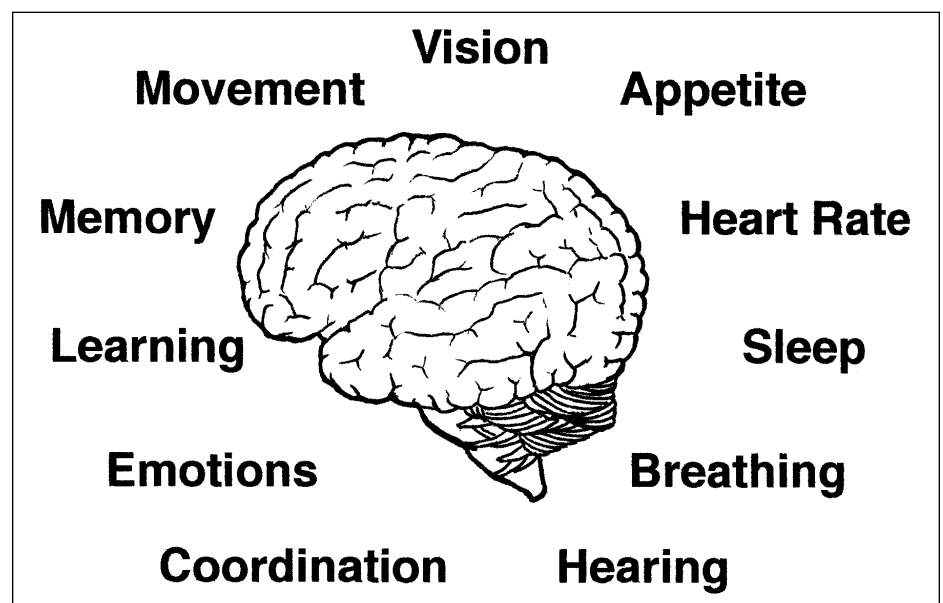


Figure 1.1: The human brain regulates everything a person does.

see, while another part is responsible for actually recognizing them. In short, specific parts of the brain carry out specific tasks. Not only that, but each part of the brain specializes in a specific kind of task. This means that whenever that task needs to be done, the appropriate information is processed by that part of the brain.

The flip side of this organizational scheme is that if a part of the brain is damaged, then the job it used to undertake cannot be done. For example, damage to the occipital lobe at the back of the brain can cause blindness, but it has no effect on a person's ability to hear or move. Because the job of seeing is highly compartmentalized, individuals who have lost one aspect of sight, such as the ability to see colors or to recognize faces, may still be able to do other visual tasks. Imagine being able to recognize someone by hearing his or her voice, but not being able to recognize his or her face when you see it.

The advantage of this localization of function is when larger jobs are parceled out throughout the brain, they all can be done at once. This "division of labor" adds great speed to our ability to perceive what is happening in the world around us, to analyze it, and then to generate appropriate responses. Dealing with information in this way is called **parallel processing**.¹ Computer scientists have used this concept in the development of computers.

The human brain consists of several large regions each of which is responsible for some of the activities necessary for life. These include the brainstem, cerebellum, limbic system, diencephalon, and cerebral cortex.^{2,3}

The **brainstem** is the part of the brain that connects the brain and spinal cord.

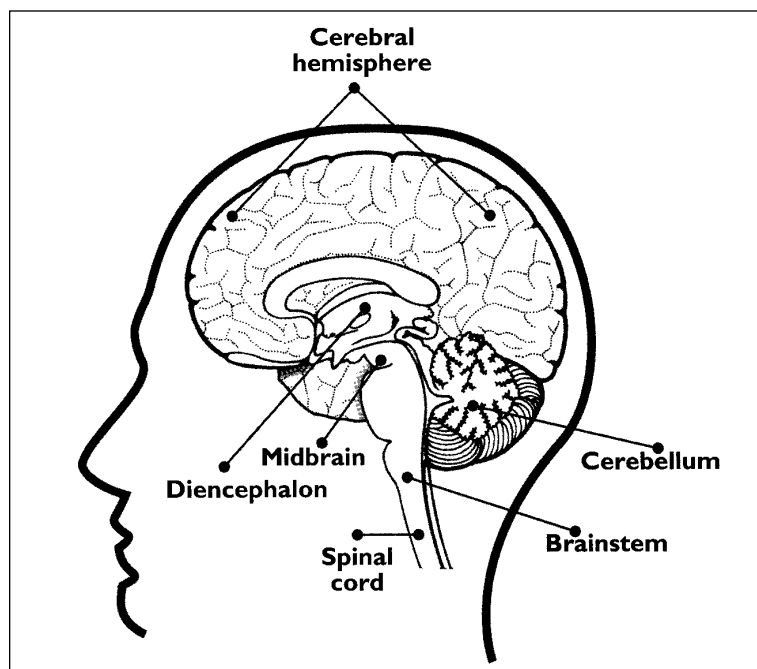


Figure 1.2: This drawing of a brain cut in half illustrates some of the major regions of the brain. Source: National Institute on Drug Abuse (1997) Mind Over Matter: The Brain's Response to Drugs, Teacher's Guide.

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This part of the brain is involved in coordinating many basic functions such as heart rate, breathing, eating, and sleeping.

The **cerebellum** coordinates the brain's instructions for skilled repetitive movements and for maintaining balance and posture.

The **limbic system**, as discussed in the next section, is involved in regulating emotions and motivations. In addition, parts of the limbic system, the amygdala and hippocampus, are important for memory functions.

The **diencephalon** contains the thalamus and hypothalamus. The thalamus is involved in sensory perception and the regulation of movement. The hypothalamus is an important regulator of the pituitary gland.

The **cerebral cortex** makes up the largest part of the brain mass and lies over and around most of the other brain structures. It is the part of the brain that is responsible for thinking, perceiving, and producing and understanding language. The cortex can be divided into areas that are involved in vision, hearing, touch, movement, smell, and thinking and reasoning.

Drugs Act On the Reward System in the Brain

Just as specific areas of the brain control seeing and hearing, specific brain areas also regulate emotions and motivations. These functions are carried out by a part of the brain called the **limbic system**. The limbic system, similar to other regions in the brain, influences how we respond to the world around us. Imag-

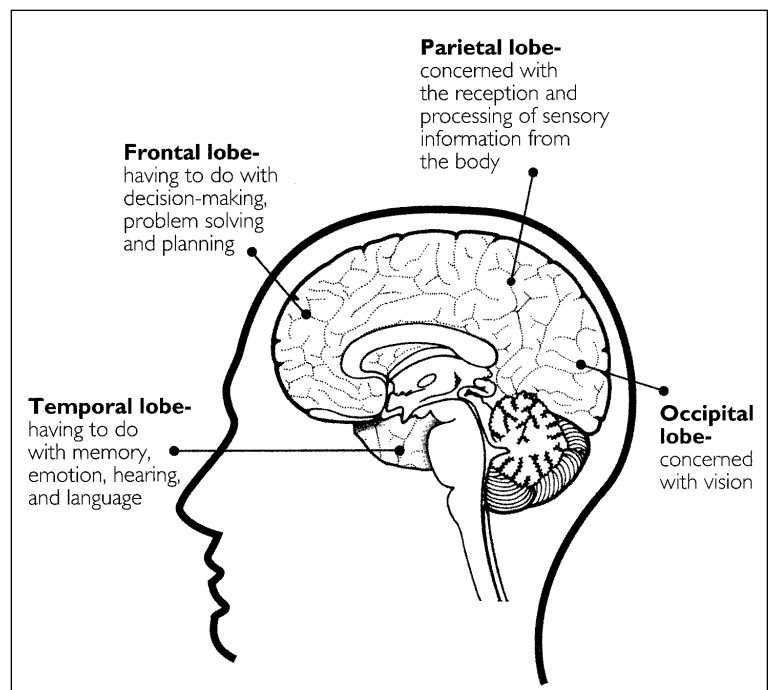


Figure 1.3: This drawing of a brain cut in half illustrates the lobes of the cerebral cortex and describes their main functions. Source: National Institute on Drug Abuse (1997) Mind Over Matter: The Brain's Response to Drugs, Teacher's Guide.

ine a cool sunny day. You finish your work early and head to your favorite park for a leisurely walk with your dog. You are feeling so mellow that you merely scratch the dog behind the ears when he slobbers on your clean shirt. You might have a very different reaction on another day when you have to work late, traffic is backed up, and the dog runs away instead of coming to welcome you home. This time when the dog slobbers on you (after he finds his way home again), you shove him away and scold him.

The feelings you have in those two different situations are a result of your limbic system at work. The limbic system uses memories, information about how your body is working, and current sensory input to generate your emotional responses to current situations.

The limbic system is involved in many of our emotions and motivations, particularly those related to survival, such as fear and anger. The limbic system also regulates feelings of pleasure related to our survival, such as those experienced from eating and sex. The feelings of pleasure, which scientists call reward, are very powerful. If something is pleasurable or rewarding, you want to do it again. Life-sustaining activities such as eating and sex activate a circuit of specialized nerve cells that are devoted to producing and regulating pleasure. These cells are located at the top of the brainstem in the **ventral tegmental area (VTA)**. These neurons relay their messages through their axons to nerve cells in a limbic system structure called the **nucleus accumbens**. Additional nerve fibers reach part of the frontal region of the cerebral cortex. This circuit of neurons is called the **reward system**.^{1,2}

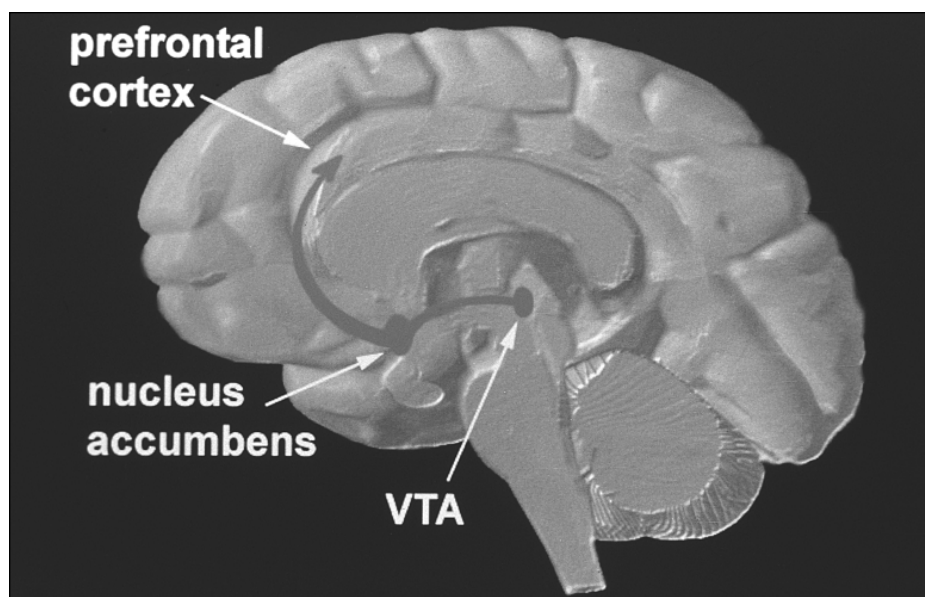


Figure 1.4: This drawing of a brain cut in half illustrates the brain areas and systems involved in the reward system, or pleasure circuit. Neurons in the ventral tegmental area (VTA) extend axons to the nucleus accumbens and part of the prefrontal cortex. Source: National Institute on Drug Abuse (1996) *The Brain & the Actions of Cocaine, Opiates, and Marijuana*. Slide Teaching Packet for Scientists.

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Drugs of abuse activate these same VTA and nucleus accumbens neurons; that is why drugs produce pleasurable feelings to the drug user. And, because the feelings are pleasurable, the user wants to continue to experience the pleasure that he or she felt during previous drug use. One of the reasons that drugs of abuse can exert such powerful control over our behavior is that they act directly on the more evolutionarily primitive brainstem and limbic structures, which can override the cortex in controlling our behavior.

Different drugs of abuse affect the neurons of the reward system in different ways. The activities in Lesson 3 in this module will elucidate the mechanisms by which drugs of abuse exert their effects.

Imaging the Brain

Scientists increasingly use newer technologies to learn more about how the brain works and how drugs of abuse change how the brain works. Historically, scientists could examine brains only after death, but new imaging procedures enable scientists to study the brain in living animals, including humans.

One of the most extensively used techniques to study brain activity and the effects of drugs on the brain is **positron emission tomography (PET)**. PET measures the spatial distribution and movement of radioisotopes in tissues of living subjects. Because the patient is awake, the technique can be used to investigate the relationship between behavioral and physiological effects and changes in brain activity. PET scans can detect nanomolar concentrations of tracer molecules and achieve spatial resolution of about 4 millimeters. In addition, computers can reconstruct images obtained from a PET scan in two or three dimensions.

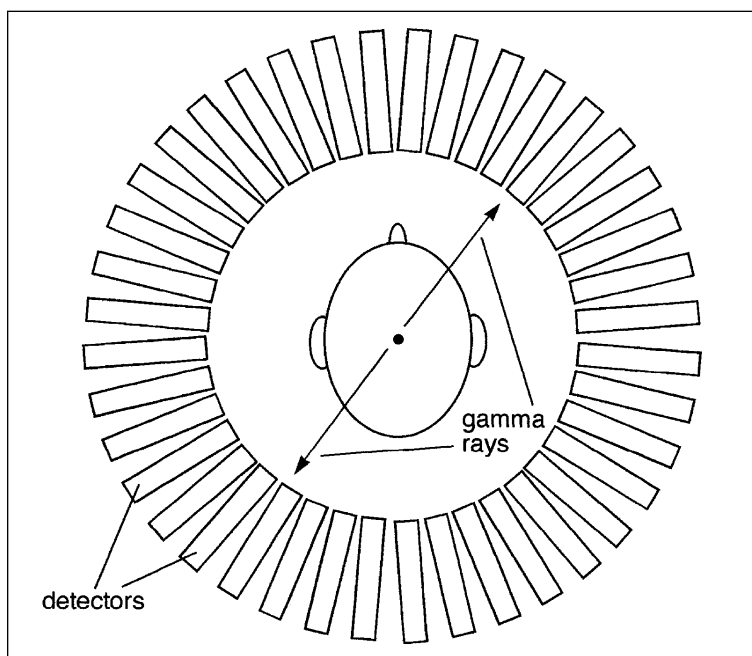


Figure 1.5: When an unstable positron collides with an electron, the particles are annihilated and two gamma rays are emitted at 180° from each other. Detectors record gamma ray emission to localize the site of positron annihilation.

PET requires the use of compounds that are labeled with positron-emitting isotopes.^{4,5} A cyclotron accelerates protons into the nucleus of nitrogen, carbon, oxygen, or fluorine to generate these isotopes. The additional proton makes the isotope unstable. To become stable again, the proton must break down into a neutron and a positron. The unstable positron travels away from the site of generation and dissipates energy along the way. Eventually, the positron collides with an electron leading to the emission of two gamma rays at 180 degrees from one another. The gamma rays reach a pair of detectors that record the event. Because the detectors respond only to simultaneous emissions, scientists can precisely map the location where the gamma rays were generated. The labeled radioisotopes

are very short-lived. The half-life (the time for half of the radioactive label to disintegrate) of the commonly used radioisotopes ranges from approximately two minutes to less than two hours, depending on the specific compound. Because a PET scan requires only small amounts (a few micrograms) of short-lived radioisotopes, negative pharmacological effects are imperceptible.

PET scans can answer a variety of questions about brain function, including the activity of neurons. Scientists use different radiolabeled compounds to investigate different biological questions. For example, radiolabeled glucose can identify parts of the brain that become more active in response to a specific stimulus. Active neurons metabolize more glucose than inactive neurons. Active neurons will emit more positrons. This will show as red or yellow on PET scans compared to blue or purple in areas where the neurons are not highly active. PET also helps scientists investigate how drugs affect the brain by enabling them to:

- determine the distribution of a drug in the body,
- measure the local concentration of a drug at binding sites,
- estimate receptor occupancy based on competitive binding assays,
- evaluate the effects of drugs on other neurotransmitter systems, and
- investigate the activity of enzymes that metabolize the drug.⁶

In addition to its uses in research, PET also is a powerful tool for diagnosing

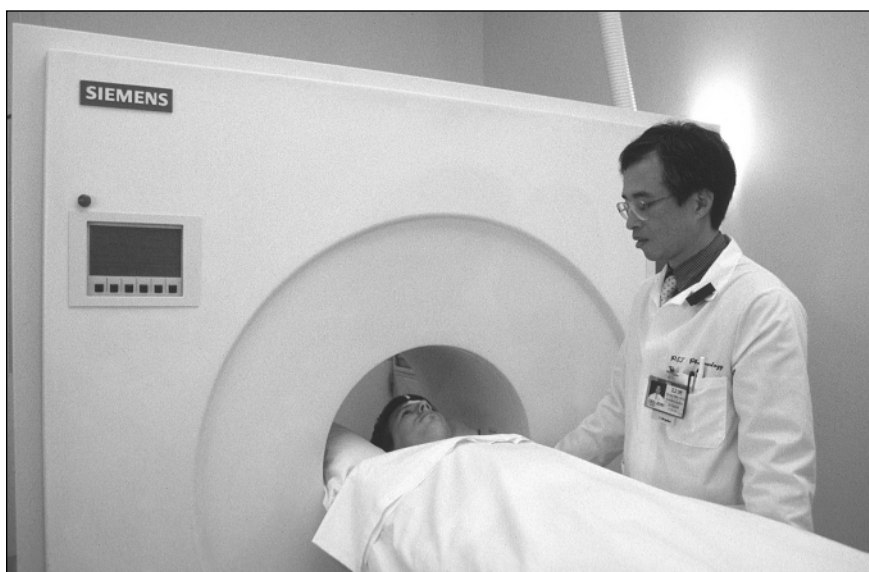


Figure 1.6: Photograph of PET imaging equipment. Photo courtesy of UCLA School of Medicine.

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Different Neuroimaging Techniques Provide Different Information About the Brain

PET scanning is a major neuroimaging technique used in drug abuse research. However, researchers also use other techniques when they better answer a scientific question. Similar to PET, single photon emission computed tomography (SPECT), magnetic resonance imaging (MRI), and electroencephalography (EEG) are noninvasive procedures that can measure biological activity through the skull and reveal the living brain at work.^{4,8} Each technique has its own advantages and each provides different information about brain structure and function. Scientists often use more than one technique when conducting their research studies.



Figure 1.7: MRI image of human brain. Photo courtesy of Penrad Imaging, Colorado Springs, CO.

Similar to PET, SPECT imaging uses radioactive tracers and a scanner to record data that a computer constructs into two- or three-dimensional images of active brain regions. Because the tracers used in SPECT take longer to deteriorate than those for PET, longer periods of time between tests are required for SPECT. While PET is more versatile than SPECT and produces more detailed images with a higher degree of resolution, SPECT is much less expensive than PET and can address many of the same drug abuse research questions.

MRI uses magnetic fields and radio waves to produce high-quality two- or three-dimensional images of brain structures without injecting radioactive tracers. In this procedure, a large cylindrical magnet creates a magnetic field around the research volunteer's head, and radio waves are sent through the magnetic field. Sensors read the signals and a computer uses the information to construct an image. Using MRI, scientists can image both surface and deep brain structures with a high degree of anatomical detail, and they can detect minute changes in these structures over time. A modification of this technique, called functional MRI (fMRI), enables scientists to see images of blood flow in the brain as it occurs. fMRI provides superior image clarity along with the ability to assess blood flow and brain functions in just a few seconds. However, PET retains the

advantage of being able to identify which brain receptors are being activated by neurotransmitters, abused drugs, and potential treatment compounds.

EEG uses electrodes placed on the scalp to detect and measure patterns of electrical activity in the brain. The greatest advantage of EEG is speed: it can record complex patterns of neural activity occurring within fractions of a second after a stimulus has been administered. The drawback to EEG is that it does not provide the spatial resolution of fMRI or PET. Researchers often combine EEG images of brain electrical activity with MRI scans to localize brain activity more precisely.

and monitoring certain diseases.⁷ For example, PET scans may be used to locate tumors in cancer patients, monitor the spread of cancer, and evaluate the effectiveness of cancer treatment. PET scans are able to reveal the presence of tumors because of the rapid metabolism characteristic of cancerous cells. PET images reveal this increased glucose utilization by cells that have high metabolic rates. PET is an accurate test for coronary heart disease because it can detect areas of diminished blood flow to the heart. Doctors also employ PET to reveal changes in the brain that occur with Alzheimer's disease, Parkinson's disease, or seizure disorders. PET is a valuable tool because it:

- is safe,
- replaces multiple testing procedures with a single exam,
- can detect diseases before they show up on other tests,
- can show the progress of disease, and
- reduces or eliminates the need for invasive procedures such as surgery.⁷

| CD-ROM Activities | |
|-------------------|--------|
| Activity Number | CD-ROM |
| Activity 1 | no |
| Activity 2 | yes |
| Activity 3 | yes |
| Activity 4 | no |
| Activity 5 | no |

| Photocopies | | |
|--|---|---|
| For the class | For each group of 3 students | For each student |
| 1 transparency of Master 1.3, <i>PET Image Tasks</i> 1 transparency of Master 1.4, <i>Major Regions of the Brain</i> 1 transparency of Master 1.5, <i>Areas of the Cerebral Cortex and Their Functions</i> 1 transparency of Master 1.7, <i>The Reward System</i> | 1 copy of Master 1.1, <i>Positron Emission Tomography (PET) Images</i> ^a 1 copy of Master 1.2, <i>Interpreting PET Images</i> | 1 copy of Master 1.6, <i>What Happened to Phineas Gage?</i> |

^a The CD-ROM version of Activity 2 is the preferred approach. Copies of Master 1.1, *Positron Emission Tomography (PET) Images*, are needed only if the CD-ROM is unavailable for classroom use. If needed, make one set of color photocopies for each team of 3 students. Several field-test teachers laminated the color copies to help preserve them.

| Materials | |
|------------|---|
| Activity 1 | 6 to 8 index cards (3" x 5" or 4" x 6") |
| Activity 2 | overhead projector |
| Activity 3 | overhead projector |
| Activity 4 | none |
| Activity 5 | overhead projector |

Preparation

Prepare task cards for Activity 1, Step 1 (see page 30). Decide which tasks you wish students to do. Write the instructions for each task on an index card.

Arrange for the class to use the computer lab for Activities 2 and 3.

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Procedure



This activity is designed to engage students in learning about the brain and to help the teacher assess the students' prior knowledge of the scope of functions regulated by the human brain.

ACTIVITY 1: WHAT DOES THE BRAIN DO?

1. Ask for 6-8 volunteers (one for each task) to participate in an activity. Ask them to come to the front of the room, and give each volunteer one of the prepared task cards. Then ask each volunteer, one at a time, to perform the task listed on his or her task card.

The specific tasks can and should be very diverse. The following list suggests some appropriate tasks:

- wave hands in the air
- eat
- hop up and down on the right foot
- walk around the classroom
- look out the window
- recite the Pledge of Allegiance
- sing "Mary Had a Little Lamb"
- do an algebra problem (e.g., Solve the following problem: $5x + 14 = 34$. What is the value of x ?)
- recall and describe the way to get from the classroom to the cafeteria (e.g., Give directions to walk from this classroom to the cafeteria.)
- read a sentence aloud (e.g., Read the following sentence aloud: "Four score and seven years ago our fathers brought forth on this continent, a new nation, conceived in Liberty, and dedicated to the proposition that all men are created equal."⁹)

2. After the volunteers perform the tasks, ask the students to identify the part of the body that is involved in *all* of the tasks.

The goal for this question is for students to acknowledge that the brain is involved in regulating all human physiological, behavioral, and emotional functions. For example, point out that all students are breathing. When most people think about breathing, they think about the lungs, but not the involvement of the brain. Also, point out that each student's heart is beating. Although the heart is actually pumping the blood, the brain fulfills an important role in regulating the heartbeat. The involvement of the brain will be more obvious for some of the tasks than for others.

3. After students deduce that the brain is involved in all of these activities, ask students to suggest how they think scientists investigate what happens in the human brain.

Students will provide a variety of answers, including watching a person's behavior, electrical shocks, various imaging techniques (such as PET scans, CT scans, or MRI), using animals (either living or dead) for research, and so forth.

ACTIVITY 2: POSITRON EMISSION TOMOGRAPHY AND BRAIN FUNCTION



The following procedures describe how to conduct the CD-ROM version of this activity, which is the preferred method of instruction. Instructions for conducting the alternative print version follow.

1. Before starting the computer-based activity, inform students that they will be analyzing positron emission tomography (PET) images. Scientists use PET to investigate the function of the living human brain. The PET images that the students will examine use radioactive glucose to identify parts of the brain that are active. Active brain areas use more glucose than less active areas and thus more of the labeled glucose is taken up into the active areas. PET images are color-coded by a computer. The most active brain areas are shown in red. Areas in yellow are less active than the areas in red, but are more active than the areas in green. The least active areas are shown in blue or purple.

PET images are color-coded by computer to show activity in the brain. Students will see a color scale on the screen with the PET images for reference.

Students may have seen color-coded computer images on television weather reports. In weather radar images, areas encountering heavy storms appear in red and yellow, and areas experiencing milder weather disturbances appear in green or blue.

2. Divide the class into groups of three students. Arrange for each group to work at a computer to complete the CD-ROM activity, *Analyzing Brain Images*. Give each group a copy of Master 1.2, *Interpreting PET Images*.

Load the CD-ROM on the computers. From the main menu on the CD-ROM, select *The Brain: What's Going on In There?* and then click on *Analyzing Brain Images*.

3. Instruct students to work with their group members to analyze the PET images and to answer the questions on Master 1.2. When students reach question #5, display a transparency of Master 1.3, *PET Image Tasks*, to provide the needed information.
4. After the groups complete the activity and write their answers to the questions on Master 1.2, discuss the answers to the questions as a class.

SAMPLE ANSWERS TO QUESTIONS ON MASTER 1.2

Question 1. *When you look at the images that make up Set #1, how do the four images differ from each other?*

The brain images are different sizes. The images show variation in the amount and pattern of the different colors.

Question 2. *Why are four images shown in each set of PET images? Why would scientists need to examine more than one PET image taken of a subject's brain?*



Content Standard A:

Formulate and revise scientific explanations and models using logic and evidence.

Content Standard A:

Scientists rely on technology to enhance the gathering and manipulation of data.

Content Standard C:

Organisms have behavioral responses to internal changes and to external stimuli.



Content Standard A:

Abilities Necessary to do Scientific Inquiry. Communicate and defend a scientific argument.

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The four PET images in each set show the activity at different levels of the brain. If a scientist examines only a single image, he or she could miss important information.

Question 3. When comparing the images in Set #1 to the images in Sets #2, 3, 4, 5, and 6, how is the activity of the brain in each of these sets different from Set #1?

| Set Number | Identify the image that shows the greatest change (a, b, c, or d) | Describe the change in brain activity |
|------------|---|---|
| 2 | b | There is more red on the right side of the brain, mainly near the center in terms of front-to-back direction. There is also red on the left side, but it is not as strong as on the right side. |
| 3 | b | The main activation is in the back of the brain on both sides of the midline. |
| 4 | c | The main activation is at the front of the brain near the periphery on both sides of the midline. |
| 5 | d | The main activation is in four areas, two on each side of the brain. Two are very near the back of the brain, and two are farther forward. |
| 6 | a | The main areas of activation are a spot on the left side of the brain and a smaller spot near the front of the brain on the midline. |

Question 4. The PET images shown in Set #1 show brain activity in a resting brain. The images in Sets #2-6 show activity in the brains of humans who are doing different tasks. When you look at the PET scans and the chart in question #3, what generalizations can you make about the activity of the brain when different tasks are performed?

The key points of this exercise are different brain areas are activated during different tasks, and different brain functions are localized to different brain areas.

Question 5. Compare the tasks that the subject performed during each of the PET scans (as shown on the overhead transparency) to the individual's brain activity. Use the information from the overhead and from the PET images to complete the following chart.

| Set Number | Name of the brain region that is more active in the PET image | This part of the brain is involved in processing information related to |
|------------|---|---|
| 2 | auditory cortex | hearing |
| 3 | primary visual cortex | vision, sight |
| 4 | frontal cortex | thinking |
| 5 | hippocampus | memory |
| 6 | motor cortex | movement |

5. Instruct students to watch the CD-ROM video *How PET Works*.

From the Main Menu, select *The Brain: What's Going On In There?* Then click on *How is PET Done?*

This video expands students' understanding of PET. A scientist explains how PET imaging is done.

After students have completed the activity, you may wish to challenge them by asking them to propose an explanation for why functions are localized to specific brain areas. Why would this be beneficial from an evolutionary standpoint? (See Background Information on pages 22–23.)



Content Standard E: Understandings about Science and Technology. Science often advances with the introduction of new technology.

ALTERNATE VERSION OF ACTIVITY 2 FOR CLASSES WITHOUT ACCESS TO COMPUTERS



The following procedure provides instruction for completing Activity 2 without the use of the computer. Use this version if your students do not have access to computers equipped with a CD-ROM drive.

1. Tell students that one of the ways that scientists investigate the function of the living human brain is by using positron emission tomography (PET). The PET images that the students will examine use radioactive glucose to identify parts of the brain that are active. Active brain areas use more glucose than less active areas and thus more of the labeled glucose is taken up into the active areas. PET scans are color-coded. The scale bar shown on Master 1.1, *Positron Emission Tomography (PET) Images*, with the PET images provides a reference. The most active brain areas are shown in red. Areas in yellow are less active than the areas in red, but are more active than the areas in green. The least active areas are shown in blue or purple.

PET images are color-coded by computer to show activity in the brain. This is similar to color-coded images students may have seen on television weather reports. In weather radar images, areas encountering heavy storms appear in red and yellow, and areas experiencing milder weather disturbances appear in green or blue.

2. Divide the class into groups of three students. Give each group a copy of Master 1.1, *Positron Emission Tomography (PET) Images* and a copy of Master 1.2, *Analyzing Positron Emission Tomography (PET) Images*.
3. Help students understand how the PET images correlate to the orientation of the brain in the body.

The PET images show a cross-section of the brain. The four images in each set show four different levels of the brain. In these images, the front of the brain is toward the top (the subject's face is toward the top of the image.) Have the students examine the PET scans and identify the regions that become active in response to each stimulus.



Content Standard A: Formulate and revise scientific explanations and models using logic and evidence.

Content Standard A: Scientists rely on technology to enhance the gathering and manipulation of data.

Content Standard C: Organisms have behavioral responses to internal changes and to external stimuli.

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Content Standard A:
Abilities Necessary to do Scientific Inquiry. Communicate and defend a scientific argument.



Content Standard C:
Cells can differentiate and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells.



Remember, the names of the parts of the brain are not the important concepts that students need to learn. Rather, this is a way for students to relate what they have learned about localization of brain function to other activities and thus reinforce the concept that different brain regions control different functions.

4. Instruct students to work with their group members to answer the questions on Master 1.2. When students reach question #5, display a transparency of Master 1.3, *PET Image Tasks*, to provide the needed information.

5. Discuss the answers to the questions on Master 1.2 as a class.

Answers for the questions on Master 1.2 are listed in the procedure for the CD-ROM version of Activity 2 on pages 31–32.

ACTIVITY 3: PARTS OF THE BRAIN

Note to teachers: This activity is intended for classes that want more information about the anatomy of the brain. Learning the names and functions of brain lobes and regions is *not* a major focus and could distract some students from the main concept that brain functions are localized to specific brain areas. Understanding the main concept is critical for understanding how neurons communicate and how drugs of abuse affect neuronal function. These topics are covered in Lessons 2 and 3.



1. Have students continue in their groups to conduct the segment of the CD-ROM titled, *What Does This Part of the Brain Do?*

To access this CD-ROM piece, on the main menu, select *The Brain: What's Going On In There?* Then click on *What Does This Part of the Brain Do?*

ALTERNATE VERSION OF ACTIVITY 3 FOR CLASSES WITHOUT ACCESS TO COMPUTERS



1. Display a transparency of Master 1.4, *Major Regions of the Brain*, that shows major brain regions and Master 1.5, *Areas of the Cerebral Cortex and Their Function*, that shows the lobes of the cerebral cortex and their general functions.

2. Ask students to take out their completed worksheet on Master 1.2. Review the tasks that the students performed in Step 1 of Activity 1 and ask students to identify the part of the brain that was active in each case.

From the information in question #5 on Master 1.2, students should be able to identify the brain area involved in some of the tasks performed in Step 1, but others were not covered in that question. Also, for some of the activities listed more than one function is involved. For example, reciting the Pledge of Allegiance requires both memory and speech. Be aware that this chart is very simplified. Virtually all mental functions involve more than one brain area.

| Activity | General Functions Involved | Brain Area(s) Involved* |
|--|----------------------------|--|
| breathing | | brainstem (medulla) |
| heart rate | | brainstem (medulla) |
| waving hands in the air | movement | cerebrum—frontal lobe (motor cortex) cerebellum |
| hopping up and down on the right foot | movement | cerebrum—frontal lobe (motor cortex) cerebellum |
| walking around the classroom | movement | cerebrum—frontal lobe (motor cortex) cerebellum |
| looking out the window | vision | cerebrum—occipital lobe (primary visual cortex) |
| reciting the Pledge of Allegiance | speech/memory | cerebrum—frontal lobe hippocampus |
| doing an algebra problem | thinking | cerebrum—frontal lobe |
| remembering directions to get from the classroom to the school cafeteria | memory | hippocampus |
| reading a sentence | speech | cerebrum—parietal lobe and frontal lobe |

*This is very simplified. Most mental functions involve more than one area of the brain.

ACTIVITY 4: WHO WAS PHINEAS GAGE?

1. Give each student a copy of Master 1.6, *What Happened to Phineas Gage?*

Instruct students to read the story and answer the questions.

Phineas Gage was injured in an accident in the 1800s. His recovery from the injury and the resulting change in personality and behavior gave scientists new insight into brain function.^{10, 11}



Figure 1.8: Computer reconstruction of the skull of Phineas Gage illustrating the projection of the tamping rod through the brain. Reprinted with permission from Damasio H, Grabowski T, Frank R, Galaburda AM, Damasio AR: The return of Phineas Gage: Clues about the brain from a famous patient. *Science* 264: 1102-1105. Department of Neurology and Image Analysis Facility, University of Iowa. Copyrighted 1994 *American Association for the Advancement of Science*.

Content Standard A: Scientists rely on technology to enhance the gathering and manipulation of data.

Content Standard C: Multicellular animals have nervous systems that generate behavior.

Content Standard G: Usually, changes in scientific knowledge occur as small modifications in extant knowledge.

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SAMPLE ANSWERS TO QUESTIONS ON MASTER 1.6

Question 1. How did Phineas Gage change after the accident?

After the accident, Gage's personality changed. He was no longer the likeable and responsible person he was prior to the accident. Instead he was irresponsible and used profanity.

Question 2. How did Phineas Gage's accident change scientists' understanding of the brain?

Scientists learned that the brain does more than control language and movement. It also controls emotions and social behaviors. Equally important, scientists learned that the brain processes information for specific functions in specific brain areas.



Content Standard C:
Multicellular organisms have nervous systems that generate behavior.
Content Standard F:
An individual's mood and behavior may be modified by substances.



If students understand that PET images reveal changes in brain activity and that drugs activate the reward system in the brain, students should predict that the reward system (the VTA and nucleus accumbens) should be more active after an individual takes drugs. These brain areas should appear red or yellow in PET scans taken after drug use whereas they would be purple or blue in PET images taken before drug use.

ACTIVITY 5: WHERE DO DRUGS ACT?

- 1. Now that students understand that different areas in the brain process specific types of stimuli, ask students to consider things that make them feel good, or are pleasurable. How might doing something pleasurable change brain activity?**

If students understand, from Activity 2 of this lesson, that brain functions are localized to specific brain areas, they should suspect that things that make them feel pleasure will stimulate a specific brain region.

- 2. Display the transparency of Master 1.7, *The Reward System*. Tell students that part of the brain produces and regulates feelings of pleasure, which scientists call reward. This brain region is called the reward system. The parts of the brain that make up the reward system are the ventral tegmental area (VTA), nucleus accumbens, and part of the frontal region of the cerebral cortex. This brain region responds to life-sustaining activities such as eating and drinking, as well as species-sustaining sexual activity.**
- 3. Introduce students to the idea that drugs of abuse activate the brain's reward system, or pleasure circuit. Drugs alter the way in which the reward system functions. Drugs also act on other regions of the brain, but their action in the reward system makes the drug abuser feel pleasure and want to continue taking drugs.**

Students will learn more about how drugs exert these effects in the remaining lessons in this curriculum supplement.

- 4. Ask students to hypothesize how PET images of a person's brain would change after taking drugs of abuse.**

Currently, PET technology is not sensitive enough to allow scientists to visualize this reward system activation. The VTA and nucleus accumbens are too small for PET images to detect significant activity changes. Scientists have relied on other technologies to learn that drugs of abuse do activate these brain regions.

Some students may hypothesize that PET images of the brain after drug abuse would also show changes in other regions of the brain. This is correct. Drugs do affect other regions of the brain, but it is the reward system that gives the pleasurable feelings associated with drug use. More information on the more widespread effects of drugs on the brain is presented in Lesson 4.